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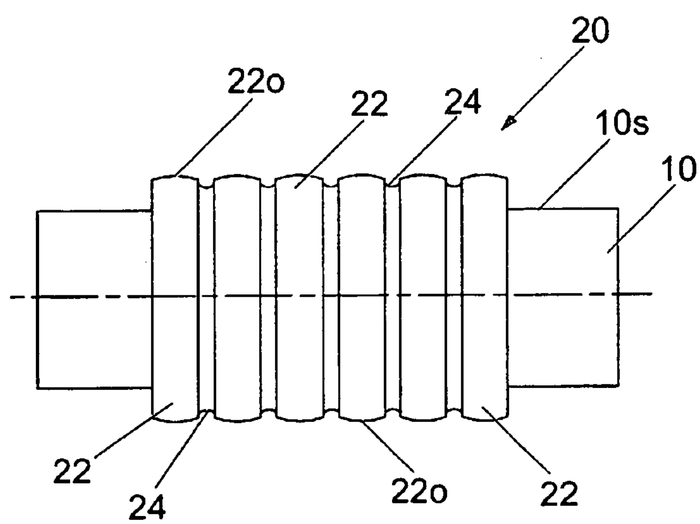
(54) Title: DEVICE AND METHOD TO SEAL BOREHOLES



(57) Abstract: Apparatus and methods are described that are particularly suited for creating a seal in a borehole annulus. In one embodiment, an outer surface 10s of an expandable conduit (10) is provided with a formation (20) that includes an elastomeric material (e.g. a rubber) that can expand and/or swell when the material comes into contact with an actuating agent (e.g. water, brine, drilling fluid etc.). The expandable conduit (10) is located inside a second conduit (e.g. a pre-installed casing, liner or open borehole) and radially expanded. The actuating agent can be naturally occurring in the borehole or can be injected or pumped therein to expand or swell the elastomeric material to create the seal.

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DEVICE AND METHOD TO SEAL BOREHOLES

The present invention relates to apparatus and methods for sealing an annulus in a borehole. The present invention can also be used to seal and lock expandable tubular members within cased, lined, and in particular, open-hole boreholes.

It is known to use expandable tubular members, e.g. liners, casing and the like, that are located in a borehole and radially expanded in situ by applying a radial expansion force using a mechanical expander device or an inflatable element, such as a packer. Once the expandable member has been expanded into place, the member may not contact the conduit (e.g. liner, casing, formation) in which it is located along the entire length of the member, and a seal is generally required against the liner, casing or formation to prevent fluid flow in an annulus created between the expandable member and the liner, casing or formation, and also to hold differential pressure. The seal also helps to prevent movement of the

expandable member that may be caused by, for example, expansion or contraction of the member or other tubular members within the borehole, and/or accidental impacts or shocks.

When running and expanding in open-hole applications or within damaged or washed-out casing, liner etc, the diameter of the borehole or the casing, liner etc may not be precisely known as it may vary over the length of the borehole because of variations in the different materials in the formation, or variations in the internal diameter of the downhole tubulars. In certain downhole formations such as washed-out sandstone, the size of the drilled borehole can vary to a large extent along the length or depth thereof.

According to a first aspect of the present invention, there is provided a seal for use in a borehole, the seal comprising an elastomeric material that is capable of expanding upon contact with an actuating agent.

According to a second aspect of the present invention, there is provided a method of creating a seal in a borehole, the method comprising the steps of providing an elastomeric material in the borehole and exposing the material to an actuating agent that causes the elastomeric material to expand.

The seal is preferably expanded in an annulus to seal the annulus or a portion thereof.

The elastomeric material is typically a rubber. The elastomeric material can be NITRILE™, VITON™, AFLAS™, Ethylene-propylene rubbers (EPM or EPDM) or KALREZ™, although other suitable materials may also be used. Any elastomeric material may be used. The choice of elastomeric material will largely depend upon the particular application and the actuating agent. Also, the fluids that are present downhole will also determine which elastomeric material or actuating agent can be used.

The actuating agent typically comprises a water- or mineral-based oil or water. Production and/or drilling fluids (e.g. brine, drilling mud or the like) may also be used. Hydraulic oil may be used as the actuating agent. Any fluid that reacts with a particular elastomeric material may be used as the actuating agent. The choice of actuating agent will depend upon the particular application, the elastomeric material and the fluids that are present downhole.

The actuating agent may be naturally occurring downhole, or can be injected or pumped into the borehole. Alternatively, a container (e.g. a bag) of the actuating agent can be located at or near the elastomeric material where the container bursts upon radial expansion of the conduit. Thus, the actuating agent comes into contact with the elastomeric material causing it to expand and/or swell.

The elastomeric material is typically applied to an outer surface of a conduit. The conduit can be any downhole tubular, such as drill pipe, liner, casing or the like. The conduit is preferably capable of being radially expanded, and is thus typically of a ductile material.

The conduit can be a discrete length or can be in the form of a string where two or more conduits are coupled together (e.g. by welding, screw threads etc). The elastomeric material can be applied at two or more axially spaced-apart locations on the conduit. The elastomeric material is typically applied at a plurality of axially spaced-apart locations on the conduit.

The conduit is typically radially expanded. The conduit is typically located in a second conduit before being radially expanded. The second conduit can be a borehole, casing, liner or other downhole tubular.

The elastomeric material can be at least partially covered or encased in a non-swelling and/or non-expanding elastomeric material. The non-swelling and/or non-expanding elastomeric material can be an elastomer that swells in a particular fluid that is not added or injected into the borehole, or is not naturally occurring in the borehole. Alternatively, the non-swelling and/or non-expanding elastomeric

material can be an elastomer that swells to a lesser extent in the naturally occurring, added or injected fluid.

As a further alternative, a non-swelling polymer (e.g. a plastic) may be used in place of the non-swelling and/or non-expanding elastomeric material. The non-swelling polymer can be TEFLON™, RYTON™ or PEEK™.

The elastomeric material may be in the form of a formation. The formation can comprise one or more bands of the elastomeric material, the bands typically being annular. Alternatively, the formation may comprise two outer bands of a non-swelling and/or non-expanding elastomeric material (or other rubber or plastic) with a band of swelling elastomeric material therebetween. A further alternative formation comprises one or more bands of elastomeric material that are more or less covered or encased in a non-swelling and/or non-expanding elastomeric (or other) material. At least a portion of the elastomeric material is typically not covered by the non-swelling and/or non-expanding material. The uncovered portion of the elastomeric material typically facilitates contact between the material and the actuating agent. Other formations may also be used.

The elastomeric material typically swells upon contact with the actuating fluid due to absorption of

the fluid by the material. Alternatively, or additionally, the elastomeric material can expand through chemical attack resulting in a breakdown of cross-linked bonds.

The elastomeric material typically expands and/or swells by around 5% to 200%, although values outwith this range are also possible. The expansion and/or swelling of the elastomeric material can typically be controlled. For example, restricting the amount of actuating agent can control the amount of expansion and/or swelling. Also, reducing the amount of elastomeric material that is exposed to the actuating agent (e.g. by covering or encasing more or less of the material in a non-swelling material) can control the amount of expansion and/or swelling. Other factors such as temperature and pressure can also affect the amount of expansion and/or swelling, as can the surface area of the elastomeric material that is exposed to the actuating agent.

Optionally, the expansion and/or swelling of the elastomeric material can be delayed for a period of time. This allows the conduit to be located in the second conduit and radially expanded before the elastomeric material expands and/or swells. Chemical additives can be combined with the base formulation of the swelling elastomeric material to delay the swelling for a period of time. The period of time can be anything from a few hours to a few days. The particular chemical additive that is used typically

depends upon the structure of the base polymer in the elastomeric material. Pigments such as carbon black, glue, magnesium carbonate, zinc oxide, litharge and sulphur are known to have a slowing or delaying influence on the rate of swelling.

As an alternative to this, a water- or other alkali-soluble material can be used, where the soluble material is at least partially dissolved upon contact with a fluid, or by the alkalinity of the water.

The method typically includes the additional step of applying the elastomeric material to an outer surface of a conduit. The conduit can be any downhole tubular, such as drill pipe, liner, casing or the like. The conduit is preferably capable of being radially expanded, and is thus typically of a ductile material.

The method typically includes the additional step of locating the conduit within a second conduit. The second conduit may comprise a borehole, casing, liner or other downhole tubular.

The method typically includes the additional step of applying a radial expansion force to the conduit. The radial expansion force typically increases the inner and outer diameters of the conduit. The radial expansion force can be applied using an inflatable element (e.g. a packer) or an expander device (e.g. a cone). The conduit can be rested on top of the

inflatable element or the expander device as it is run into the second conduit.

The method typically includes the additional steps of providing an expander device and pushing or pulling the expander device through the conduit. The expander device is typically attached to a drill string, coiled tubing string, wireline or the like, but can be pushed or pulled through the second conduit using any conventional means.

Alternatively, the method typically includes the additional steps of providing an inflatable element and actuating the inflatable element. The inflatable element can be attached to a drill string, coiled tubing string or wireline (with a downhole pump). Optionally, the method may include one, some or all of the additional steps of deflating the inflatable element, moving it to another location, and re-inflating it to expand a further portion of the conduit.

The method optionally includes the additional step of injecting or pumping the actuating agent into the borehole.

The method optionally includes the additional step of temporarily anchoring the conduit in place. This provides an anchor point for the radial expansion of the conduit. A packer, slips or the like can be used for this purpose. The inflatable element is

optionally used to expand a portion of the conduit against the second conduit to act as an anchor point.

Embodiments of the present invention shall now be described, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a first embodiment of a formation applied to an outer surface of a conduit;

Fig. 2 is a second embodiment of a formation applied to an outer surface of a conduit;

Fig. 3a is a third embodiment of a formation applied to an outer surface of a conduit; and

Fig. 3b is a cross-sectional view through a portion of the conduit of Fig. 3a.

Referring to the drawings, Fig. 1 shows a conduit 10 that is provided with a first embodiment of a formation 20 on an outer surface 10s thereof. The formation 20 includes a plurality of bands 22 that are rounded on their outer edges 22o and are joined by a plurality of valleys 24 therebetween. The bands 22 and valleys 24 provide an overall ribbed profile to the formation 20.

Formation 20 is typically comprised of an elastomeric material that can expand and/or swell due to contact with an actuating agent such as a fluid. The expansion and/or swelling of the elastomeric material results in increased dimensional properties of the elastomeric material in the formation 20. That is, the material forming the bands 22 and valleys 24 will

expand or swell in both the longitudinal and radial directions, the amount of expansion or swelling depending on the amount of actuating agent, the amount of absorption thereof by the elastomeric material and the amount of the elastomeric material itself. It will also be appreciated that for a given elastomeric material, the amount of swelling and/or expansion is a function not only of the type of actuating agent, but also of physical factors such as pressure, temperature and the surface area of material that is exposed to the actuating agent.

The expansion and/or swelling of the elastomeric material can take place either by absorption of the actuating agent into the porous structure of the elastomeric material, or through chemical attack resulting in a breakdown of cross-linked bonds. In the interest of brevity, use of the terms "swell" and "swelling" or the like will be understood also to relate to the possibility that the elastomeric material may additionally, or alternatively expand.

The elastomeric material is typically a rubber material, such as NITRILE™, VITON™, AFLAS™, Ethylene-propylene rubbers (EPM or EPDM)and KALREZ™. The actuating agent is typically a fluid, such as hydraulic oil or water, and is generally an oil- or water-based fluid. For example, brine or other production or drilling fluids (e.g. mud) can be used to cause the elastomeric material to swell. The actuating agent used to actuate the swelling of the

elastomeric material can either be naturally occurring in the borehole itself, or specific fluids or chemicals that are pumped or injected into the borehole.

The type of actuating agent that causes the elastomeric material to swell generally depends upon the properties of the material, and in particular the hardening matter, material or chemicals used in the elastomeric material.

Table 1 below gives examples of fluid swell for a variety of elastomeric materials, and the extent to which they swell when exposed to certain actuating agents.

Table 1

Material	Swelling Media (at 300°F)	
	Expansion with Hydraulic Oil	Expansion With Water
NITRILE™	15%	10%
VITON™	10%	20%
AFLAS™	30%	12%
EPDM	200%	15%
KALREZ™	5%	10%

As indicated above, the amount of swelling of the elastomeric material depends on the type of actuating agent used to actuate the swelling, the amount of actuating agent and the amount and type of

elastomeric material that is exposed to the actuating agent. The amount of swelling of the elastomeric material can be controlled by controlling the amount of fluid that is allowed to contact the material and for how long. For example, the material may only be exposed to a restricted amount of fluid where the material can only absorb this restricted amount. Thus, swelling of the elastomeric material will stop once all the fluid has been absorbed by the material.

The elastomeric material can typically swell by around 5% (or less) to around 200% (or more), depending upon the type of elastomeric material and actuating agent used. If the particular properties of the material and the amount of fluid that the material is exposed to are known, then it is possible to predict the amount of expansion or swelling. It is also possible to predict how much material and fluid will be required to fill a known volume.

The structure of the formation 20 can be a combination of swelling or expanding and non-swelling or non-expanding elastomers, and the outer surfaces of the formation 20 may be profiled to enable maximum material exposure to the swelling or expanding medium. In the interest of brevity, non-swelling and non-expanding elastomeric material will be referred to commonly by "non-swelling", but it will be appreciated that this may include non-expanding elastomeric materials also.

The formation 20 is typically applied to the outer surface 10s of the conduit 10 before it is radially expanded. Conduit 10 can be any downhole conduit that is capable of sustaining plastic and/or elastic deformation, and can be a single length of, for example, liner, casing etc. However, conduit 10 may be formed of a plurality of lengths of casing, liner or the like that are coupled together using any conventional means, e.g. screw threads, welding etc.

Formation 20 is typically applied at axially spaced-apart locations along the length of conduit 10, although it may be provided continuously over the length of the conduit 10 or a portion thereof. It will be appreciated that the elastomeric material will require space into which it can swell, and thus it is preferable to have at least some spacing between the formations 20. The elastomeric material of the or each formation 20 is typically in a solid or relatively solid form so that it can be attached or bonded to the outer surface 10s and remain there as the conduit 10 is run into the borehole, casing, liner or the like.

Once the borehole has been drilled, or in the case of a borehole that is provided with pre-installed casing, liner or the like, conduit 10 is located in the borehole, casing, liner or the like and radially expanded using any conventional means. This can be done by using an inflatable element (e.g. a packer) or an expander device (e.g. a cone) to apply a radial

expansion force. The conduit 10 typically undergoes plastic and/or elastic deformation to increases its inner and outer diameters.

The expansion of conduit 10 is typically not sufficient to expand the outer surface 10s into direct contact with the formation of the borehole or pre-installed casing, liner or the like, although this may not always be the case. For example, certain portions of the conduit 10 may contact the formation at locations along its length due to normal variations in the diameter of the borehole during drilling, and/or variations in the diameter of the conduit 10 itself. Thus, an annulus is typically created between the outer surface 10s and the borehole, casing, liner etc.

It will be appreciated that the elastomeric material in the or each formation 20 may begin to swell as soon as the conduit 10 is located in the borehole as the fluid that actuates the swelling may be naturally occurring in the borehole. In this case, there is generally no requirement to inject chemicals or other fluids to actuate the swelling of the elastomeric material.

However, the elastomeric material may only swell when it comes into contact with particular fluids that are not naturally occurring in the borehole and thus the fluid will require to be injected or pumped into the annulus between the conduit 10 and the borehole,

casing, liner or the like. This can be done using any conventional means.

As an alternative to this, a bag or other such container (not shown) that contains the actuating fluid can be attached to the outer surface 10s at or near to the or each formation 20. Indeed, the bag or the like can be located over the or each formation 20. Thus, as the conduit 10 is radially expanded, the bag ruptures causing the actuating fluid to contact the elastomeric material.

It will be appreciated that it is possible to delay the swelling of the elastomeric material. This can be done by using chemical additives in the base formulation that causes a delay in swelling. The type of additives that may be added will typically vary and may be different for each elastomeric material, depending on the base polymer used in the material. Typical pigments that can be added that are known to delay or having a slowing influence on the rate of swelling include carbon black, glue, magnesium carbonate, zinc oxide, litharge and sulphur.

As an alternative, the elastomeric material can be at least partially or totally encased in a water-soluble or alkali-soluble polymeric covering. The covering can be at least partially dissolved by the water or the alkalinity of the water so that the actuating agent can contact the elastomeric material

thereunder. This can be used to delay the swelling by selecting a specific soluble covering that can only be dissolved by chemicals or fluids that are injected into the borehole at a predetermined time.

The delay in swelling can allow the conduit 10 to be located in the borehole, casing, liner or the like and expanded into place before the swelling or a substantial part thereof takes place. The delay in swelling can be any length from hours to days.

As the elastomeric material swells, it expands and thus creates a seal in the annulus. The seal is independent of the diameter of the borehole, casing, liner or the like as the material will swell and continue to swell upon absorption of the fluid to substantially fill the annulus between the conduit 10 and the borehole, casing, liner or the like in the proximity of the formation 20. As the elastomeric material swells and continues to do so, it will come into contact with the formation of the borehole, casing, liner or the like and will go into a compressive state to provide a tight seal in the annulus. Not only does the elastomeric material act as a seal, but it will also tend to lock the conduit 10 in place within the borehole, casing, liner or the like.

Upon swelling, the elastomeric material retains sufficient mechanical properties (e.g. hardness, tensile strength, modulus of elasticity, elongation

at break etc) to withstand differential pressure between the borehole and the inside of the liner, casing etc. The mechanical properties that are retained also ensure that the elastomeric material remains bonded to the conduit 10. The mechanical properties can be maintained over a significant time period so that the seal created by the swelling of the elastomeric material does not deteriorate over time.

It will be appreciated that the mechanical properties of the elastomeric material can be adjusted or tuned to specific requirements. Chemical additives such as reinforcing agents, carbon black, plasticisers, accelerators, activators, anti-oxidants and pigments may be added to the base polymer to have an effect on the final material properties, including the amount of swell. These chemical additives can vary or change the tensile strength, modulus of elasticity, hardness and other factors of the elastomeric material.

The resilient nature of the elastomeric material can serve to absorb shocks and impacts downhole, and can also tolerate movement of the conduit 10 (and other downhole tubular members) due to expansion and contraction etc.

Referring to Fig. 2, there is shown an alternative formation 30 that can be applied to an outer surface 40s of a conduit 40. Conduit 40 can be the same or

similar to conduit 10. As with formation 20, formation 30 can be applied at a plurality of axially spaced-apart locations along the length of the conduit 40. Conduit 40 may be a discrete length of downhole tubular that is capable of being radially expanded, or can comprise a length of discrete portions of downhole tubular that are coupled together (e.g. by welding, screw threads etc).

The formation 30 comprises two outer bands 32, 34 of a non-swelling elastomeric material with an intermediate band 36 of a swelling elastomeric material therebetween. It will be appreciated that the intermediate band 36 has been provided with a ribbed or serrated outer profile to provide a larger amount of material (i.e. an increased surface area) that is exposed to the actuating fluid that causes swelling. The use of the outer bands 32, 34 of a non-swelling elastomeric material can allow the amount of swelling of the intermediate band 36 of the elastomeric material to be controlled. This is because the two outer bands 32, 34 can limit or otherwise restrict the amount of swelling of the elastomeric material (i.e. band 36) in the axial directions. Thus, the swelling of the material will be substantially constrained to the radial direction.

The non-swelling elastomeric material can be an elastomer that swells in a particular fluid that is not added or injected into the borehole, or is not naturally occurring in the borehole. Alternatively,

the non-swelling elastomeric material can be an elastomer that swells to a lesser extent in the naturally occurring, added or injected fluid. For example, and with reference to Table 1 above, if hydraulic oil is being used as the actuating fluid, then the elastomeric material could be EPDM (which expands by around 200% in hydraulic oil) and the non-swelling elastomeric material could be KALREZ™ as this only swells by around 5% in hydraulic oil.

As a further alternative, a non-swelling polymer (e.g. a plastic) may be used in place of the non-swelling elastomeric material. For example, TEFLON™, RYTON™ or PEEK™ may be used.

It will be appreciated that the term "non-swelling elastomeric material" is intended to encompass all of these options.

The outer bands 32, 34 of a non-swelling elastomeric material also provides a mechanism by which the swelling of the elastomeric material in intermediate band 36 can be controlled. For example, when the conduit 10 is radially expanded, the bands 32, 34 of the non-swelling elastomeric material will also expand, thus creating a partial seal in the annulus between the outer surface 10s of the conduit 10 and the borehole, casing, liner or the like. The partial seal reduces the amount of fluid that can by-pass it and be absorbed by the swelling elastomeric material of band 36. This restriction in the flow of fluid

can be used to delay the swelling of the elastomeric material in band 36 by restricting the amount of fluid that can be absorbed by the material, thus reducing the rate of swelling.

The thickness of the bands 32, 34 in the radial direction can be chosen to allow either a large amount of fluid to seep into band 36 (i.e. by making the bands relatively thin) or a small amount of fluid (i.e. by making the bands relatively thick). If the bands 32, 34 are relatively thick, a small annulus will be created between the outer surface of the bands 32, 34 and the borehole etc, thus providing a restriction to the fluid. The restricted fluid flow will thus cause the elastomeric material to swell more slowly. However, if the bands 32, 34 are relatively thin, then a larger annulus is created allowing more fluid to by-pass it, and thus providing more fluid that can swell the elastomeric material.

Additionally, the two outer bands 32, 34 can also help to prevent extrusion of the swelling elastomer material in band 36. The swelling elastomeric material in band 36 typically gets softer when it swells and can thus extrude. The non-swelling material in bands 32, 34 can help to control and/or prevent the extrusion of the swelling elastomeric material. It will be appreciated that the bands 32, 34 reduce the amount of space into which the swelling material of band 36 can extrude and thus by reducing the space into which it can extrude, the amount of

extrusion can be controlled or substantially prevented. For example, if the thickness of the bands 32, 34 is such that there is very little or no space into which the swelling elastomeric material can extrude into, then this can stop the extrusion. Alternatively, the thickness of the bands 32, 34 can provide only a relatively small space into which the swelling elastomeric material can extrude into, thus substantially controlling the amount of extrusion.

Figs. 3a and 3b show a further formation 50 that can be applied to an outer surface 60s of a conduit 60. Conduit 60 can be the same as or similar to conduits 10, 40 and may be a discrete length of downhole tubular that is capable of being radially expanded, or can comprise a length of discrete portions of downhole tubular that are coupled together (e.g. by welding, screw threads etc).

Formation 50 comprises a number of axially spaced-apart bands 52 that are typically annular bands, but this is not essential. The bands 52 are located symmetrically about a perpendicular axis so that the seals created upon swelling of the elastomeric material within the bands hold pressure in both directions.

The bands 52 are typically lip-type seals. As can be seen from Fig. 3b in particular, the bands 52 have an outer covering 52o of a non-swelling elastomer, and an inner portion 52i of a swelling elastomeric

material. One end 52a of the band 52 is open to fluids within the borehole, whereas the outer covering 52o encases the remainder of the elastomeric material, thus substantially preventing the ingress of fluids.

The swelling of the elastomeric material in inner portion 52i is constrained by the outer covering 52o, thus forcing the material to expand out end 52a. This creates a seal that faces the direction of pressure. With the embodiment shown in Fig. 3a, four seals are provided, with two facing in a first direction and two facing in a second direction. The second direction is typically opposite the first direction. This provides a primary and a back-up seal in each direction, with the seal facing the pressure.

The outer covering 52o can also help to prevent or control the extrusion of the elastomeric material in inner portion 52i as described above.

Thus, certain embodiments of the present invention provide apparatus and methods for creating seals in a borehole that use the swelling properties of elastomeric materials to create the seals. Certain embodiments of the present invention can also prevent swelling of the material until the conduit to which it is applied has been radially expanded in situ.

Modifications and improvements may be made to the foregoing without departing from the scope of the present invention.

CLAIMS

1. A seal for use in a borehole, the seal comprising an elastomeric material that is capable of expanding or swelling upon contact with an actuating agent.

2. A seal according to claim 1, wherein the elastomeric material comprises a rubber.

3. A seal according to either preceding claim, wherein the elastomeric material is NITRILE™, VITON™, AFLAS™, Ethylene-propylene rubbers (EPM or EPDM) or KALREZ™.

4. A seal according to any preceding claim, wherein the actuating agent comprises a water- or mineral-based oil or water.

5. A seal according to any preceding claim, wherein the actuating agent is naturally occurring downhole, or is injected or pumped into the borehole.

6. A seal according to any one of claims 1 to 4, wherein a container of the actuating agent is located at or near the elastomeric material where the container bursts upon radial expansion of the conduit.

7. A seal according to any preceding claim, wherein the elastomeric material is applied to an outer surface of a conduit.

8. A seal according to claim 7, wherein the conduit is capable of being radially expanded.

9. A seal according to claim 7 or claim 8, wherein the elastomeric material is applied at two or more axially spaced-apart locations on the conduit.

10. A seal according to any one of claims 7 to 9, wherein the conduit is radially expanded.

11. A seal according to claim 10, wherein the conduit is located in a second conduit before being radially expanded.

12. A seal according to any preceding claim, wherein the elastomeric material is at least partially covered or encased in a non-swelling and/or non-expanding elastomeric material, or a non-swelling polymer.

13. A seal according to any preceding claim, wherein the elastomeric material swells upon contact with the actuating fluid due to absorption of the fluid by the material.

14. A seal according to any preceding claim, wherein the elastomeric material can expand through

chemical attack resulting in a breakdown of cross-linked bonds.

15. A method of creating a seal in a borehole, the method comprising the steps of providing an elastomeric material in the borehole and exposing the material to an actuating agent that causes the elastomeric material to expand.

16. A method according to claim 15, including the additional step of applying the elastomeric material to an outer surface of a conduit.

17. A method according to claim 16, including the additional step of locating the conduit within a second conduit.

18. A method according to claim 16 or claim 17, wherein the method includes the additional step of applying a radial expansion force to the conduit.

19. A method according to any one of claim 15 to 18, wherein the method includes the additional step of injecting or pumping the actuating agent into the borehole.

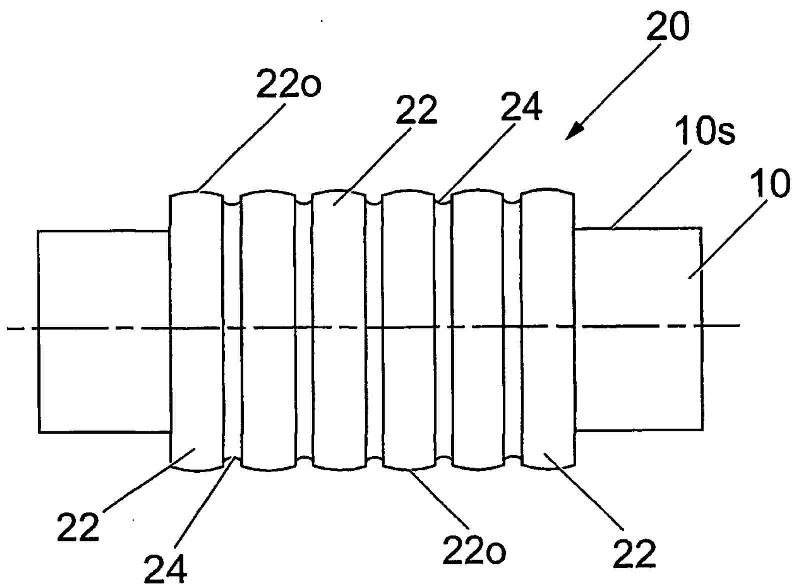

Fig. 1

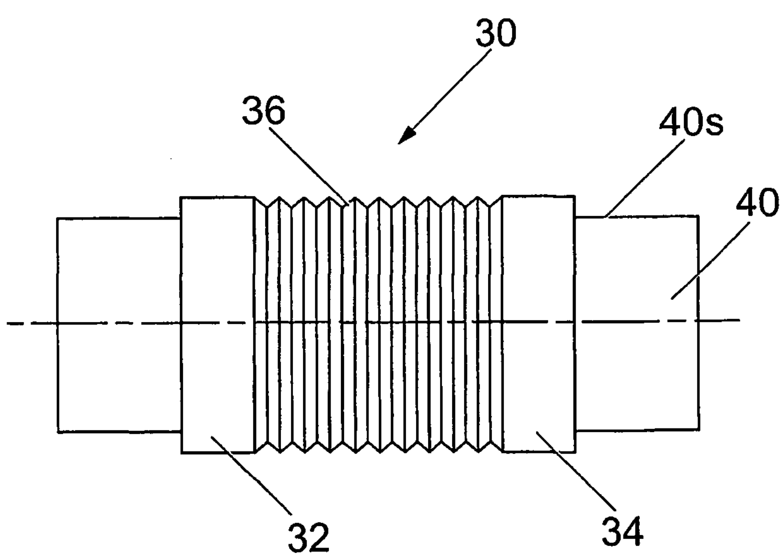

Fig. 2

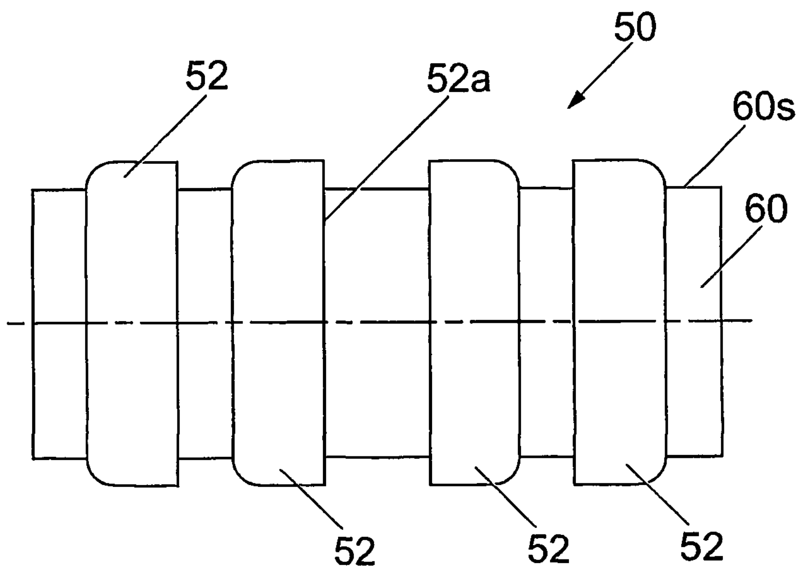

Fig. 3a

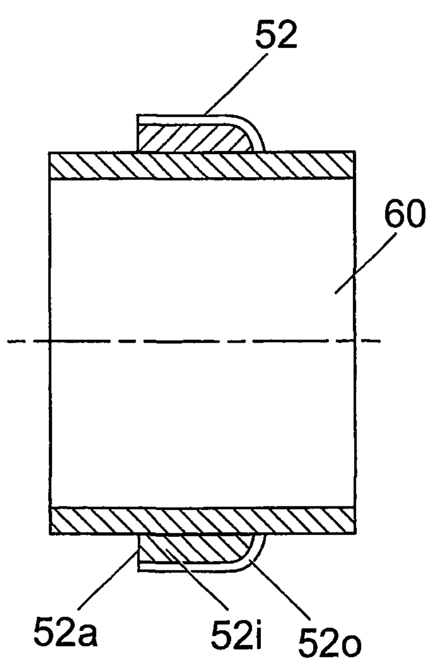

Fig. 3b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 02/00362

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E21B 33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2945541 A (GEORGE P. MALY ET AL), 19 July 1960 (19.07.60), column 1, line 34 - line 42; column 2, line 4 - line 16; column 3, line 10 - line 20	1,2,4,5,7,9, 12,13,15,16
	--	
X	US 3385367 A (PAUL KOLLSMAN), 28 May 1968 (28.05.68), column 2, line 30 - line 32; column 2, line 45 - line 50; column 2, line 72, column 4, lines 57 - 75; column 5, lines 27 - 30; column 7, lines 42 - 47; column 8, lines 27 - 39; figures	1,2,4,5,7,9, 15-17
Y		8,10,11,18
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2002	04.06.02
Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Sven-Erik Bergdahl / JA A Telephone No.

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3918523 A (STUBER), 11 November 1975 (11.11.75), column 2, line 36 - line 52; column 3, line 29 - line 52; column 3, line 65 - line 66, figures	1,2,4,5,7,9, 12,15,16,17, 19
Y		8,10,11,18
	--	
Y	WO 0037766 A2 (ASTEC DEVELOPMENTS LIMITED), 29 June 2000 (29.06.00), page 1, line 8 - line 22, figures 10,11, claim 33	8,10,11,18
	--	
X	US 4862967 A (HARRIS), 5 Sept 1989 (05.09.89), column 2, line 36 - line 45; column 3, line 14 - line 31, figures	1,2-5,7,12, 13,15,16
	--	
X	US 3740360 A (KENNETH H. NIMERICK), 19 June 1973 (19.06.73), column 1, line 32 - line 47; column 2, line 17 - line 26; column 5, line 15 - line 30, abstract, column 5, lines 48 - 55	1,3-5,13-15
	--	
X	US 4836940 A (ALEXANDER), 6 June 1989 (06.06.89), column 6, line 3 - line 10; column 8, line 8 - column 9, line 2; column 9, line 45 - line 65, abstract	1,2-5,13-15
	--	
X	US 5086841 A (REID ET AL), 11 February 1992 (11.02.92), column 1, line 10 - line 17; column 2, line 57 - column 3, line 5; column 3, line 47 - line 62	1,3-5,13-15
	--	

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/05/02

International application No.

PCT/GB 02/00362

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2945541 A	19/07/60	NONE	
US 3385367 A	28/05/68	NONE	
US 3918523 A	11/11/75	US 3946569 A	30/03/76
WO 0037766 A2	29/06/00	AU 1867900 A	12/07/00
		AU 1868700 A	12/07/00
		AU 1868800 A	12/07/00
		AU 1868900 A	12/07/00
		AU 1876600 A	12/07/00
		AU 1876800 A	12/07/00
		EP 1141515 A	10/10/01
		EP 1141517 A	10/10/01
		EP 1141518 A	10/10/01
		EP 1144802 A	17/10/01
		EP 1147287 A	24/10/01
		EP 1151180 A	07/11/01
		GB 2345308 A	05/07/00
		GB 2346400 A	09/08/00
		GB 2346632 A	16/08/00
		GB 2346909 A	23/08/00
		GB 2347445 A	06/09/00
		GB 9828234 D	00/00/00
		GB 9928941 D	00/00/00
		GB 9930166 D	00/00/00
		GB 9930396 D	00/00/00
		GB 9930397 D	00/00/00
		GB 9930398 D	00/00/00
		NO 20012596 A	27/07/01
		NO 20012597 A	27/07/01
		NO 20012598 A	30/07/01
		NO 20012599 A	30/07/01
		NO 20012600 A	30/07/01
		NO 20012865 A	07/08/01
		WO 0037767 A	29/06/00
		WO 0037768 A	29/06/00
		WO 0037771 A	29/06/00
		WO 0037772 A	29/06/00
		WO 0037773 A	29/06/00
		AU 2946099 A	11/10/99
		GB 0025433 D	00/00/00
		GB 2353387 A,B	21/02/01
		GB 9900835 D	00/00/00
		GB 0006215 D	00/00/00
		GB 9923783 D	00/00/00
		GB 9924189 D	00/00/00
US 4862967 A	05/09/89	NONE	
US 3740360 A	19/06/73	NONE	
US 4836940 A	06/06/89	NONE	

INTERNATIONAL SEARCH REPORT
Information on patent family members

01/05/02

International application No.
PCT/GB 02/00362

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5086841 A	11/02/92	US 5034139 A	23/07/91